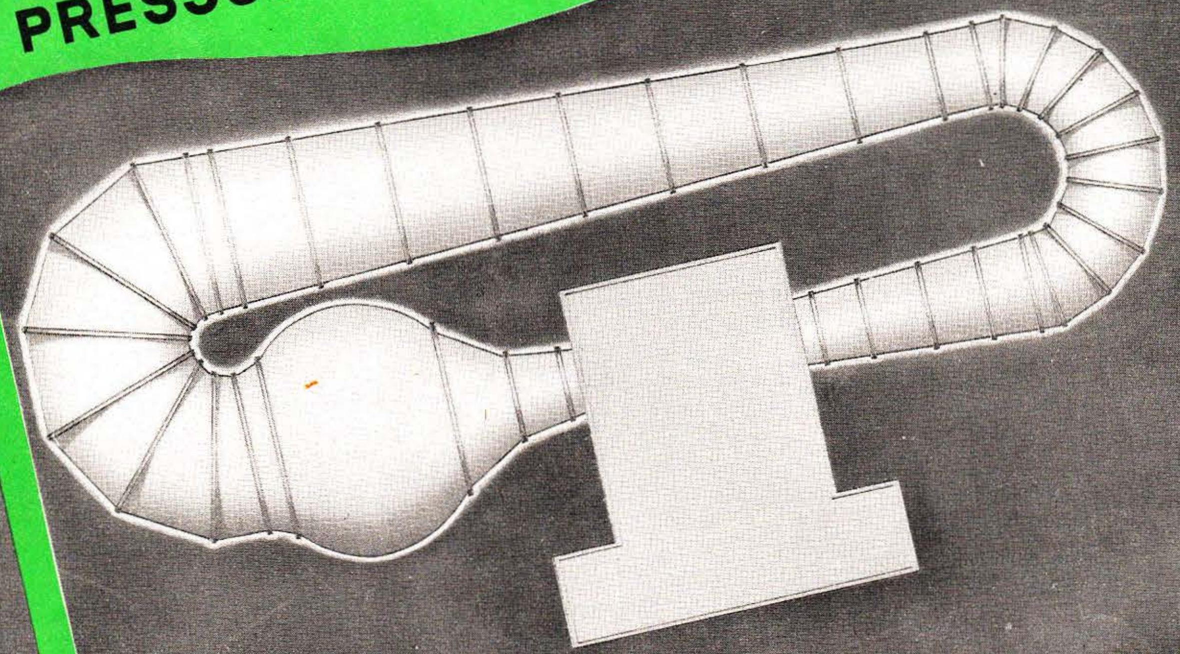
NACA

Twelve Foot

LOW TURBULENCE PRESSURE WIND TUNNEL



NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY
MOFFETT FIELD, CALIFORNIA

ON THE WISDOM WITH WHICH WE BRING SCIENCE TO BEAR AGAINST THE PROBLEMS OF THE COMING YEARS DEPENDS IN LARGE MEASURE OUR FUTURE AS A NATION."

VANNEVAR BUSH

Director, Office of Scientific Research and Development

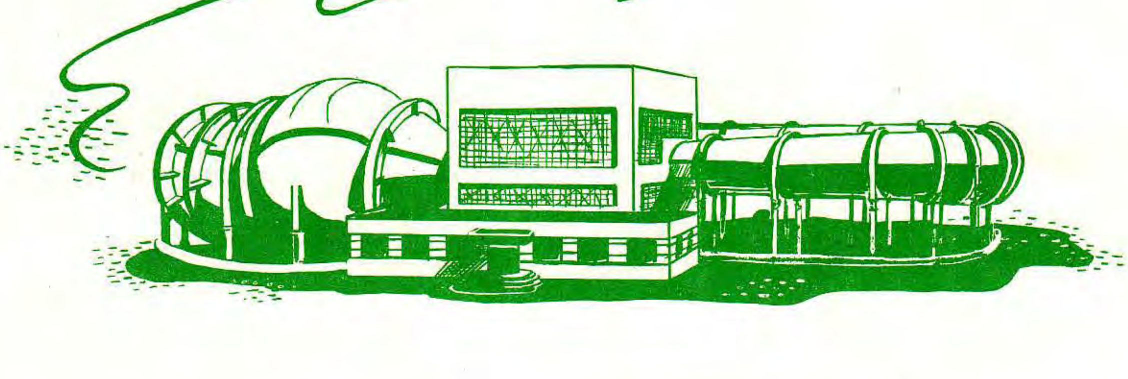
In a Report to The President of The United States, July 5, 1945

PREFACE

"Give me a lever long enough and I can move the earth. . ." This statement of Archimedes will continue to echo in the eternal corridors of time. The intelligence of man and the aid of a lever -- intellect and equipment -- can accomplish the seemingly impossible.

This is an air age. Since that epic flight by the Wright Brothers, aviation has progressed with almost unbelievable rapidity. Its story has been one of Men and Research Facilities. As the history of the National Advisory Committee for Aeronautics demonstrates, the rate of aircraft development depends greatly on the rapidity with which adequate research facilities are made available. The supporting role played by equipment in the march of aeronautics cannot be underestimated. The wind tunnel has been the greatest source of fundamental information essential to progress. Designed by engineers and physicists of the NACA and built through the approval of Congress, the Twelve Foot Low Turbulence Pressure Wind Tunnel will help meet the need for new knowledge to solve new problems that have arisen with the advent of transonic flight.

The addition of this high-speed pressure tunnel to the research facilities of the Ames Aeronautical Laboratory is another step forward in aiding American research in its never-ending task of pushing back the frontiers of the unknown.



TUNNEL COMPETED MAY 1946

SIGNIFICANCE AND PURPOSE

In the NACA Twelve Foot Low Turbulence Pressure Wind Tunnel at Ames Aeronautical Laboratory, Moffett Field, California, full-scale flight conditions can be more nearly simulated than in any other wind tunnel in existence.

Designed to operate at air speeds up to the speed of sound, the tunnel is unique in providing air flow of negligible turbulence, such as is experienced in free-atmosphere flight. Further, by pressurizing the air in the tunnel, data directly applicable to airplanes as large as full-scale attack bombers or small transport aircraft can be obtained. The tunnel size and shape was chosen for complete detailed models. The Twelve Foot Pressure Wind Tunnel is the first ever built to combine the features of very high speed, low turbulence airflow, pressurization to simulate full-scale conditions, and large size to accommodate complete models.

In the anti-turbulence sphere, which gives the Twelve Foot Tunnel its unusual shape lies the secret of achieving the unparalleled low turbulence in such a large, high-speed tunnel. The sphere, located upstream of the test section, contains eight fine mesh screens, each some sixty-three feet in diameter. These screens, higher than a six-story building, act to smooth out eddying motions in the air and produce an orderly flow. Further, the 25:1 contraction ratio from the bulge to the test section acts literally to squeeze the remaining turbulence out of the air stream. Turbulence of the flow in the test section is consequently reduced to the degree that flow conditions may be considered to approximate those normally encountered in free air. Virtual elimination of turbulence error marks a unique advance in wind-tunnel technique and usefulness in that there is no way of completely correcting for turbulence, should it exist, in application of data to free-flight conditions.

One of the most important considerations in attempting to duplicate flight conditions in a wind tunnel is the combined effects of airplane size, velocity, and density of the air. The combination of these factors, each having a known magnitude, results in an index referred to as Reynolds number. In general, the criterion for similar flow in comparing wind tunnel data with flight data is equality of Reynolds number. In this connection, the ability to vary pressure of the air circulated in the Twelve Foot Pressure Wind Tunnel from 1/6 to 6 atmospheres results in the direct control of air density, thereby allowing independent variation of Reynolds number without changing model size or air velocity. This is an important feature for many reasons. For example, by compressing the air to six times atmospheric density, a model having a 10-foot wing span may be investigated and data obtained which are directly applicable to an airplane with a 60-foot wing span, or one the size of an attack bomber.

Variation of density in the Twelve Foot Pressure Wind Tunnel from 1/6 to 6 times atmospheric density permits a wide range of tunnel air velocities with a given power input. At pressure below 1/3 atmospheric, an airspeed of 750 miles per hour is attainable.

The combination of low turbulence, wide range of velocity, and Reynolds number control gives the Twelve Foot Tunnel the distinction of being the most versatile, and, in all probability, the most economical wind tunnel in existence. Control of the important variables results not only in more directly useful data but also in great savings in research time through making possible an uninterrupted sequence of investigation of a given model or, in effect, a given airplane design.

From the viewpoint of technological advancement in aeronautics, the potentialities of the Twelve Foot Tunnel are large. The success of the NACA laminar-flow airfoil developments, as manifested in the high-speed performance of the North American "Mustang" and the Lockheed "Shooting Star", represents but a partial exploitation of the laminar-flow principles as a result of limited research facilities. The Twelve Foot Tunnel, with its large diameter test section and low turbulence provides the only research facility in which high-speed laminar-flow wings and bodies can be fully investigated and developed. It will be invaluable, too, for the full study of subsonic and transonic characteristics of supersonic airfoils and control surfaces. The tunnel will also be used to explore fully the potentialities of propellers, which have a definite future in the high-speed, high-altitude field. Critical design parameters for inlet ducts and shapes for large airflow volume engines, such as turbojets and ram-jets, are natural fields of investigation for the Twelve Foot Tunnel. Finally, complete aircraft configurations will be investigated for further knowledge of criteria for tomorrow's high-performance aircraft.

The importance of the NACA Twelve Foot Tunnel to aeronautics is the fact that a new scientific instrument has been provided which permits study with accurate control of the variables of speed, turbulence, and density in a space of time, not possible in less versatile facilities.

THE STRUCTURE

The distinctive shape of the Twelve Foot Tunnel is a direct outgrowth of the tunnel's functions--to provide non-turbulent airflow at high speed and at high pressure. The sphere, with its anti-turbulence screens, is largely responsible for the smoothness of airflow through the test section. U-turns at the tunnel ends, as opposed to the four right-angle turns usually employed in wind-tunnel design, are a structural answer to the stresses imposed by pressure.

Because of the wide range of forces from high pressure to partial vacuum employed in tunnel operation, the tunnel shell is made of welded steel plate. Full pressure inside the shell is six times the weight of the atmosphere at sea level, or an internal force of 12,600 pounds on each square foot of the tunnel shell. When evacuated to one-sixth atmosphere, the force is in the other direction, and the shell is subjected to a collapsing load of five-sixths of the atmosphere's weight, or a total of approximately 12,000 tons.

Thickness of the shell plate varies at different sections of the tunnel, from 3/4 inches downstream of the test section where the tunnel is small and the load is smallest, to 2-1/4 inches in the large section just ahead of the anti-turbulence sphere.

The anti-turbulence sphere, which gives the Twelve Foot Tunnel its unique configuration, is a device for locating anti-turbulence screens in the largest feasible cross section ahead of the tunnel throat. The same diameter attained in a cylinder would require a great increase in tunnel length and much thicker steel plate.

Installation of the eight anti-turbulence screens posed an unusual construction problem. The widest screen strips available were only 25 feet, requiring the joining of three strips to span the 63-foot sphere interior. These screens, similar to fine window screens of 16 wires to the inch, had to be installed with reasonable tautness and perfect continuity. To avoid disturbance of airflow, the three strips were joined without overlapping edges by careful brazing, wire to wire, giving a clean seam that offered no additional obstruction to the air, and therefore introduced no wake turbulence to the airstream.

The 12-foot-diameter test section of the tunnel is encased in a thick-walled cylinder 27-1/2 feet in diameter in which pressure is maintained as in the tunnel proper by means of vents in the tunnel shell. All force measurement scales and model-support equipment are housed in this pressurized cylinder. A seven-ton removable hatch at the top of the cylinder gives access to the tunnel test section for installing and removing models.

Because of the unusual problems of movement under changes of temperature and pressure, the entire tunnel shell is permitted to float freely on 52 pin-ended column supports. Actually, there is only one rigid point of support where the tunnel shell is fixed to the forward end of the pressurized cylinder surrounding the test section. The cylinder itself is securely anchored in a block of concrete. At the downstream end of the pressurized cylinder, the tunnel shell is contained in a flexible steel pressure seal.

All pin-ended columns supporting the tunnel shell are connected to footings resting on 1,240 concrete piles sunk 50 feet in the ground. While the tunnel itself weighs over 4,000 tons, the foundations had to be designed to carry the 20,000 tons of water used in hydrostatic testing of the tunnel. For this test, which was to prove the safety of the tunnel shell under extreme pressure conditions, the tunnel was completely filled with over five million gallons of water at a pressure of 120 pounds per square inch.

TUNNEL SIDELIGHTS

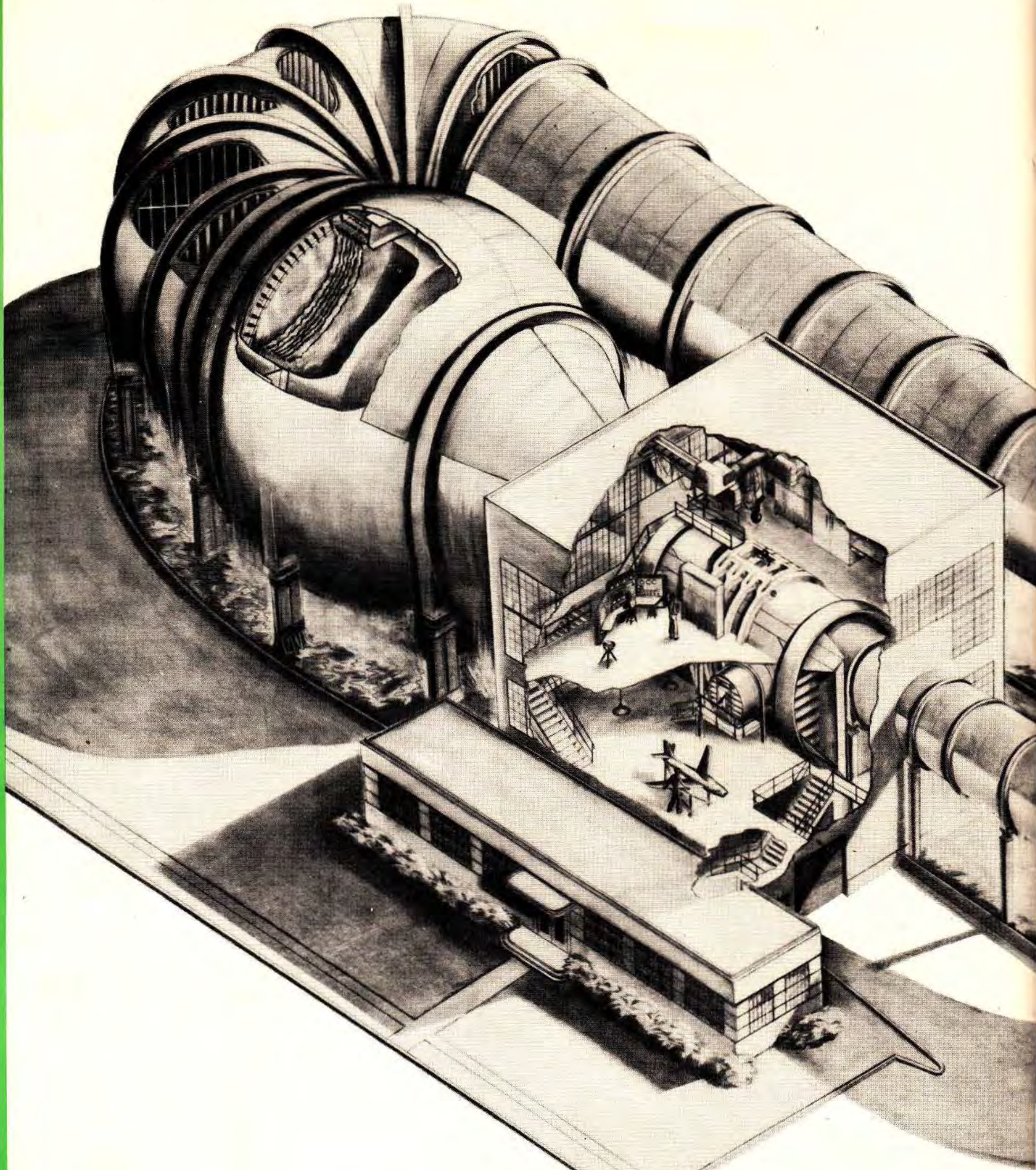
- Over 3000 tons of arc-welded steel plate were used in construction of the air-tight tunnel shell. The thickness of this plate varies from 3/4 to 2-1/4 inches.

- At high speed and maximum density, eight tons of air pass through the test section every second.

- A water spray system directly over the tunnel is used for cooling it during operation. Protection from the sun's rays is afforded by a canopy that covers the upper portion of the tunnel shell.

- The wind tunnel was filled with 5,000,000 gallons of water in its hydrostatic test. Then, as the pressure was increased, an additional 6000 gallons were required to make up for the stretching of the heavy steel shell.

- Economy in operation has been carefully considered. When a test is completed, the air is not exhausted uselessly ... instead it is used to supply the air flow to an adjacent supersonic wind tunnel.



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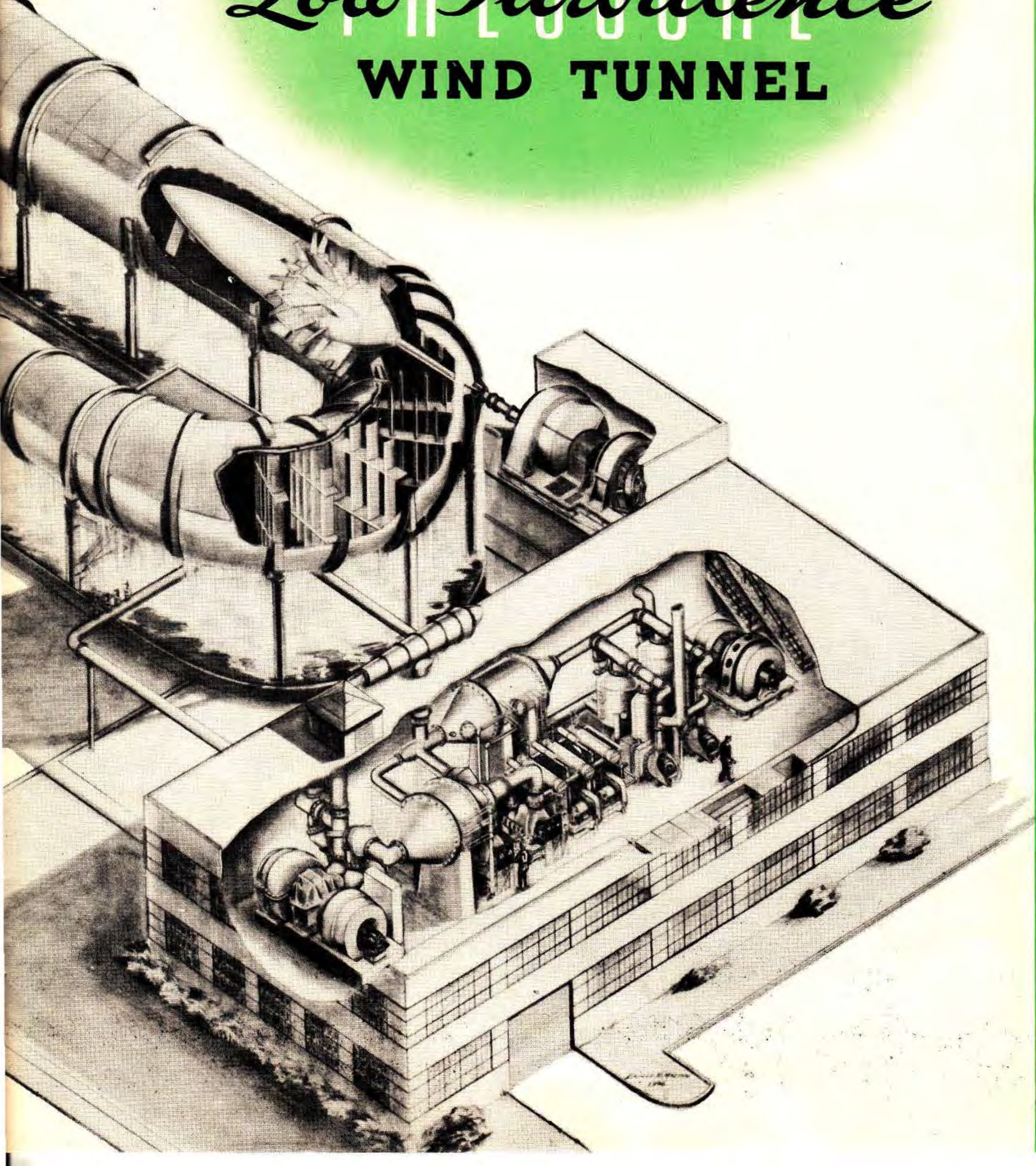
TWELVE FOOT
PRESSURE
Low Turbulence
WIND TUNNEL



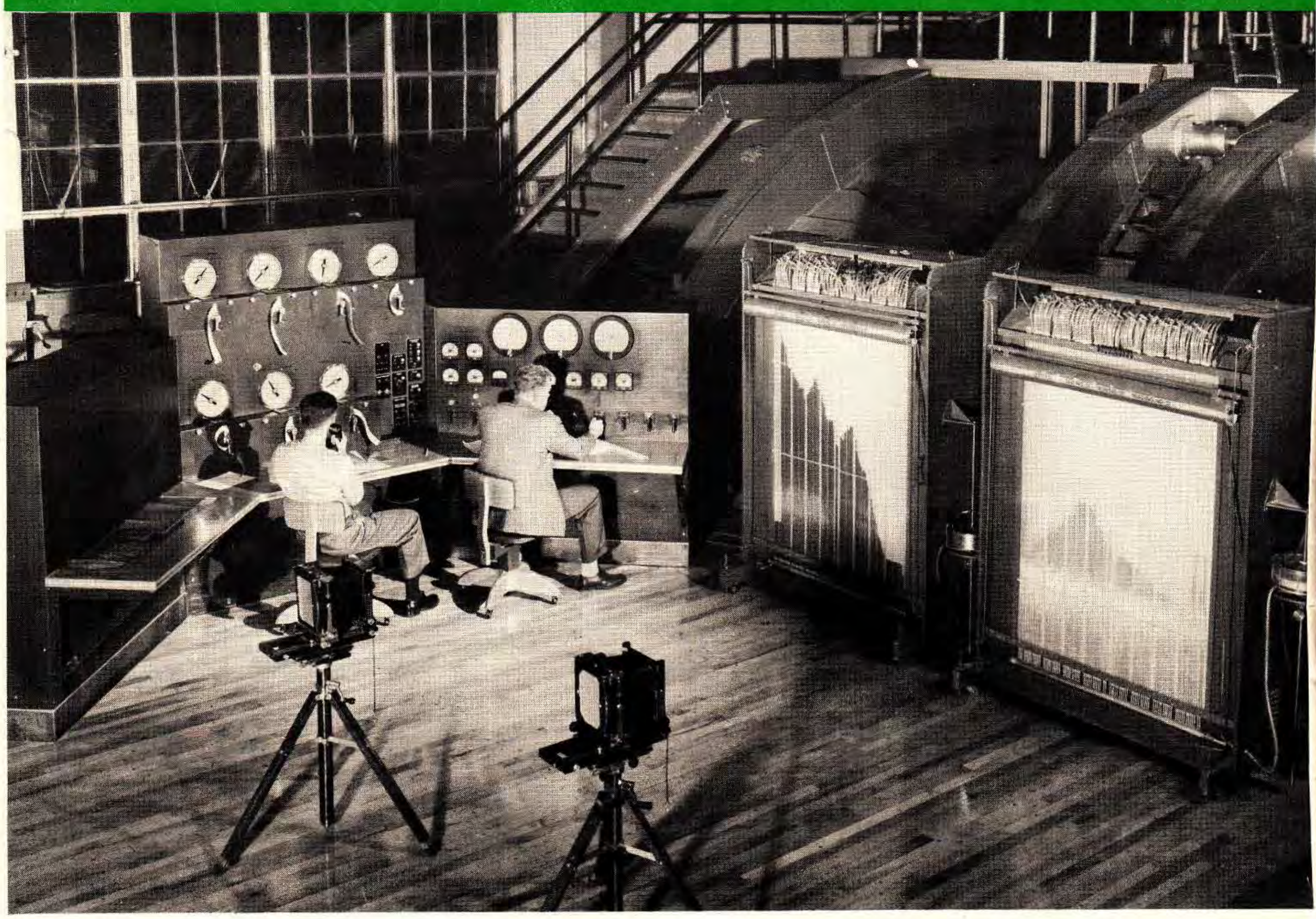
CONTROL STATION

Complete operation of the NACA Twelve Foot Tunnel and the securing of all research data are achieved at a single remote control station located adjacent to the pressurized test chamber.

From the control station, master controls automatically regulate tunnel air density and air velocity. Because a human being could not enter the pressurized tunnel without extensive deep-sea-diving equipment, changes in flight attitude of the model and all model motor and propeller regulation in powered-model investigations are remotely controlled. Since the force-measurement scales and other related equipment are located in the pressurized cylinder surrounding the test section, they too are controlled from the panel. At the touch of a button an automatic printer records forces acting on the models.

Tunnel pressure reduction is accomplished from the panel by control of the motor-operated blowdown valve located in the services building. Flow of cooling water over the tunnel shell is also regulated from the control station.

Accurate gages indicate the tunnel pressure at various points. Pressure manometers are located near the control panel and a special integrating manometer panel consisting of 61 tubes 12 feet high is used in momentum drag and wake surveys on aerodynamic bodies.



MODEL SUPPORT SYSTEM

Conventional three-point, streamlined strut supports are used for three-dimensional investigations of complete models and component parts. These struts, which also transmit the forces acting on the model to lever-type self-balancing scales, are controllable from the operator's panel for change in yaw or angle of attack.

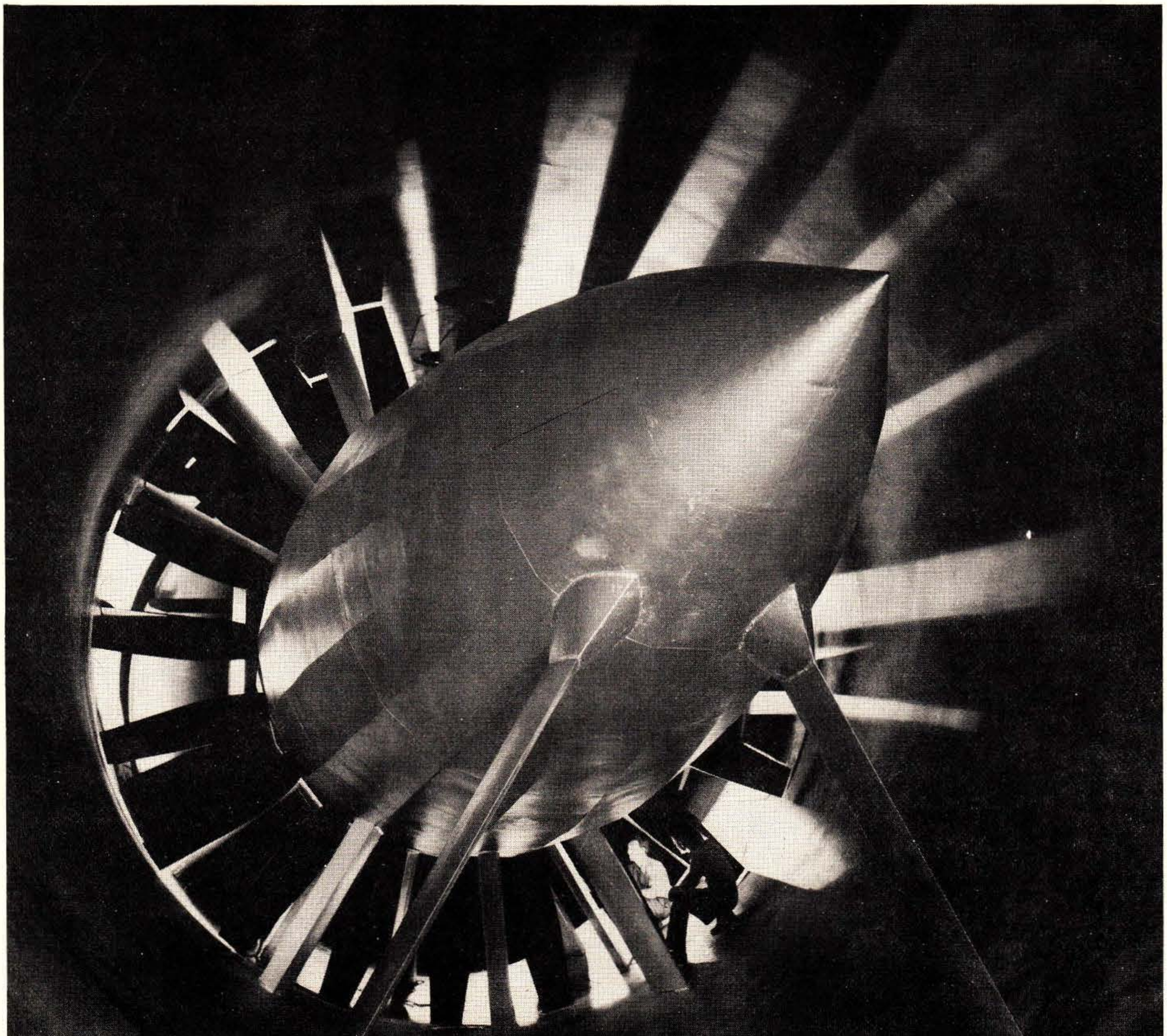
Force transfer and model-angle-changing turntable mountings are located in the sides of the tunnel wall for two-dimensional investigations of airfoils or for throat-spanning models of wing-power plant installations. A similar turntable support is located in the floor of the test section to accommodate vertical mountings of semi-span wing or tail models.

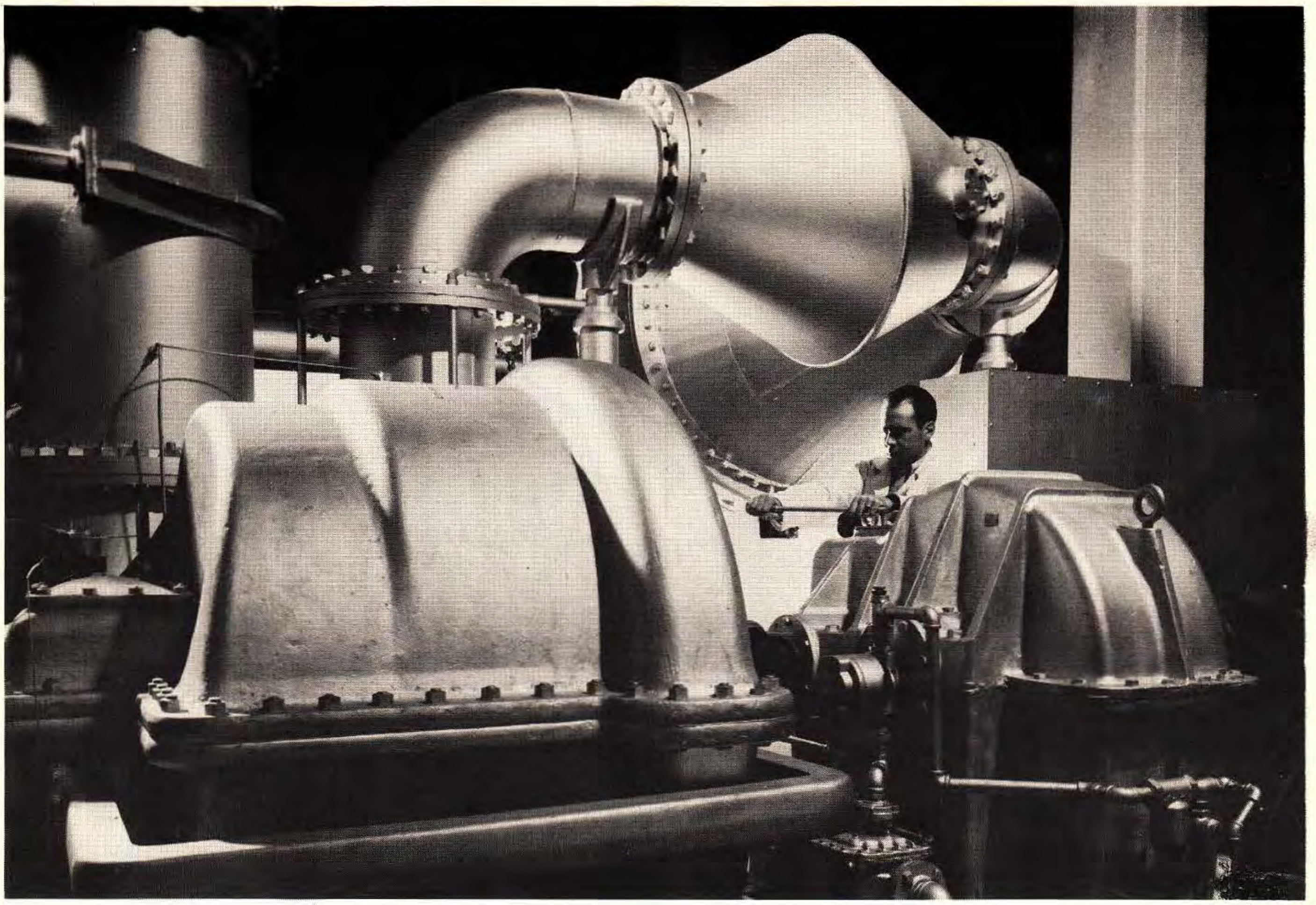
For investigating models at high speeds, a so-called sting support is used. With this kind of support the model is impaled by a rod extending rearward to a thin, airfoil-like strut spanning the throat at the downstream end. At near-critical tunnel speeds, all interference and shock occur well behind the model with the sting support, thus enhancing the accuracy of data readings on the model under investigation. Forces acting on the model are measured by compact strain gages located within the model. The sting rod is adjustable from the control panel for changes in model attitude, such as yaw and angle of attack.

TUNNEL DRIVE SYSTEM

Two 18-ton coaxial fans driven by a combination of a 9,500 horsepower a.c motor create the airflow in the Twelve Foot Tunnel. Coarse speed control is obtained by a liquid rheostat operating with the a.c. motor and fine speed control is effected through operation of the d.c. motor.

The front fan consists of 12 aluminum blades and the rear fan has 20 blades also of aluminum. Blade pitch is adjustable from the master control panel. The front fan may be uncoupled from the drive shaft through a clutch arrangement and allowed to windmill when it is not needed. The prerotation vanes in front of both fans are remotely adjustable.





POWER AND MAKE-UP AIR EQUIPMENT

Equipment rated at 15,700 horsepower is installed in the services building at the downstream end of the Twelve Foot Tunnel. Tunnel fan drive motors are rated at 11,000 horsepower capacity; the air compressor motors at 4,500 total; and the coolant compressor motor at 200 hp.

The tunnel drive motors, which cannot be located inside the tunnel shell because of the pressure, are connected to the tunnel fans by a shaft and flexible coupling. The shaft extends into the tunnel wall through a pressure seal.

Three multi-stage compressors, capable of handling a total of 25,000 cubic feet of air per minute, are employed to compress and evacuate the tunnel air. Less than two hours are required to raise the air density to six atmospheres.

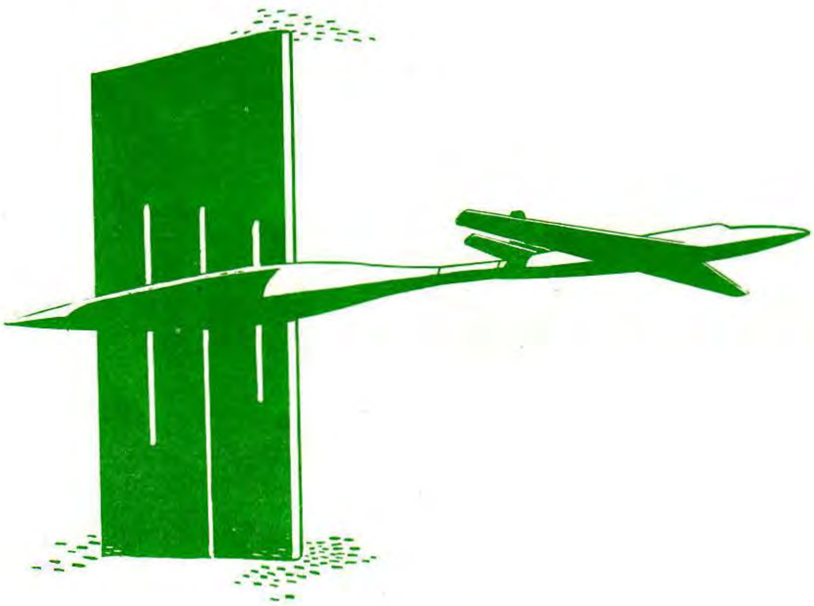
Water cooling units are used to maintain a reasonably low air temperature during the compression stages and Freon-filled refrigerating coils further lower the temperature to 40 degrees F.

To avoid condensation effects, the air humidity is controlled by large silica-gel dehumidifiers. Moisture content of the air is reduced to an equivalent of about 40 cupfuls of water for the entire tunnel volume of air, which would otherwise contain roughly 190 gallons under normal conditions.

A motor-operated blow-down valve releases the pressurized air when tunnel pressure reduction is desired. Instead of venting this pressure energy to the atmosphere, however, the NACA is constructing an intermittent-type supersonic wind tunnel to utilize air released from the Twelve Foot Tunnel. For the same reason that the "parent tunnel" yields high Reynolds number data, so will the opportunistically constructed supersonic wind tunnel provide data at large scale.

DETAILS

Tunnel length	336 feet
Working section (diameter)	12 feet
Maximum diameter (in anti-turbulence sphere)	68 feet
Contraction ratio	25 to 1
Maximum airspeed	750 mph
Maximum pressure	6 atmospheres
Vacuum	1/6 atmospheres
Number of fans	two
Diameter of fans	22 feet 8 inches
Number of blades in front fan	12
Number of blades in rear fan	20
Drive shaft	30-inch outside diameter hollow steel
Main drive power	11,000 hp
Main drive speed	490 rpm



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